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OPERATIONS RESEARCH, Inc.

SILVER SPRING, MARYLAND

RESULTS OF PRELIMINARY MICROWAVE MULTI-APPLICATIONS PAYLOAD (MMAP) STUDY

15 JUNE 1975

Contract No. NAS5-24034, Mod. 49

Prepared for

**National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771**

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1. MMAP AND EXPERIMENT DESCRIPTIONS

1.1 INTRODUCTION

The concept of integrating a set of specific microwave experiments into one payload was developed during the study of the Spacelab Application Facility. This concept has come to be known as the Microwave Multi-Applications Payload (MMAP) and consists of a set of Spacelab equipment shared by a number of experiments (presently, twelve). This system should provide a low-cost method of meeting a large number of experimental objectives by removing hardware redundancies. Furthermore, a synergism is obtained by a choice of experiments which will, in some cases, provide data to other experiments and enhance the mission results.

A preliminary feasibility study of this concept has been carried out and the results are contained in this report. The initial objectives of this study have been to determine the minimum equipment requirements of MMAP and the feasibility of placing the numerous large aperture antennas in the Spacelab. The study was begun by reviewing the experimental objectives and techniques and determining areas of commonality. Emphasis was given to the determination of common RF equipment requirements. These requirements were considered after agreement among the experimenters had been reached on limiting the number of frequencies to be used in the system. This was done so that the number of antennas, transmitters, and receivers could be minimized. The study, to this point, has considered in some detail the electronics system block diagram and the antenna configurations.

This report consists of five sections. The first contains tables which describe the experiments presently being considered for incorporation into MMAP. The second discusses concepts of the antenna configuration with descriptions of the antenna requirements for each experiment and weight and center-of-gravity estimates. The third section deals with the MMAP electronics requirements and describes the antenna and Spacelab pallet/module systems. Section 4 presents data relating to operational parameters with estimates of experiment time use. Schedule requirements for the MMAP are discussed in Section 5 and the results of the study are summarized in Section 6.

1.2 MMAP EXPERIMENT DESCRIPTION

The experiments to be incorporated into the MMAP consist of active microwave sensors with some passive instrumentation. The equipments operate over a wide region of the electromagnetic spectrum and perform tasks related to Communications and Navigation as well as the Earth and Ocean Physics, and Earth Observations disciplines. Table 1 lists the experiments to be conducted on MMAP. Tables 2 through 13 and Figures 1 and 2 briefly describe each experiment. The tables list the responsible experimenter, objective, need, and experimental technique utilized for each experiment.

TABLE 1

MICROWAVE MULTI-APPLICATIONS PAYLOAD

1. Electromagnetic Environment Experiment (EEE)
2. Millimeter Wave Communications Experiment (MMWC)
3. Adaptive Multi-Beam Antennas Experiment (AMBA)
4. Attitude/Position Location Interferometer (I/F)
5. Meteorological Radar (METRAD)
6. Surface Spectrum Radar Experiment (SUR RAD)
7. Atmospheric and Oceanographic Imaging Radiometer (A&O R/M)
8. Soil Moisture and Salinity Radiometer (SMS R/M)
9. Antenna Range Experiment (ARE)
10. Data Collection With Multi-Beam (DCMB)
11. Cooperative Surveillance by Spacelab Radar (CSSR)
12. NAVSTAR/GPS (GPS)

TABLE 2

ELECTROMAGNETIC ENVIRONMENT EXPERIMENT

Experimenter: R. Taylor

- A. OBJECTIVE: To determine spectrum utilization between 0.4 GHz and 100 GHz.
- B. NEED: To fulfill NASA Headquarters' responsibility to advise FCC in questions of spectrum use.
- C. EXPERIMENTAL TECHNIQUE:
1. 3m x 3m antenna array, 3m dish, 1.5m dish, 0.7m dish, 0.3m horn.
 2. Wideband swept receiver.
 3. Ability to beam sweep or track a ground radio source.

TABLE 3
MILLIMETER WAVE COMMUNICATIONS EXPERIMENT

Experimenter: L. J. Ippolito

A. OBJECTIVE: Implement and evaluate advanced wideband communications techniques and systems for space applications in the 20 and 30 GHz bands.

B. NEED: To develop requirements for high data rate transmissions in frequency bands above 20 GHz allocated for space applications.

C. EXPERIMENTAL TECHNIQUE:

1. Provide operational space-earth link with 400 MHz or greater bandwidth for direct evaluation of critical design parameters.
2. Develop information on wideband analog & digital communications techniques, rain attenuation, frequency re-use, spectrum allocation.

TABLE 4
ADAPTIVE MULTI-BEAM ANTENNAS EXPERIMENT

Experimenter: S. H. Durrani

- A. OBJECTIVE: To demonstrate multi-beam array, adaptive beam-forming and pointing in conjunction with ground users.
- B. NEED: To provide satellite communications for small user terminals, and to allow re-use of frequency spectrum.
- C. EXPERIMENTAL TECHNIQUE:
1. Two arrays at 1.5 and 10 GHz.
 2. Arrays electronically formed and steered in two dimensions.
 3. Time-division multiple access provided to users with satellite-switched multi-beam operation.

TABLE 5
ATTITUDE/POSITION LOCATION INTERFEROMETER

Experimenter: A. Kampinsky

- A. OBJECTIVE: To test improved techniques of very accurate attitude and inertial position measurements.
- B. NEED: To accurately determine ground position and attitude reference for other experiments, particularly meteorological radar, optical radiometers, millimeter wave instruments.
- C. EXPERIMENTAL TECHNIQUE:
1. Two-dimensional microwave interferometer.
 2. Triangulation from ground transmitters.
 3. Multi-band operation.

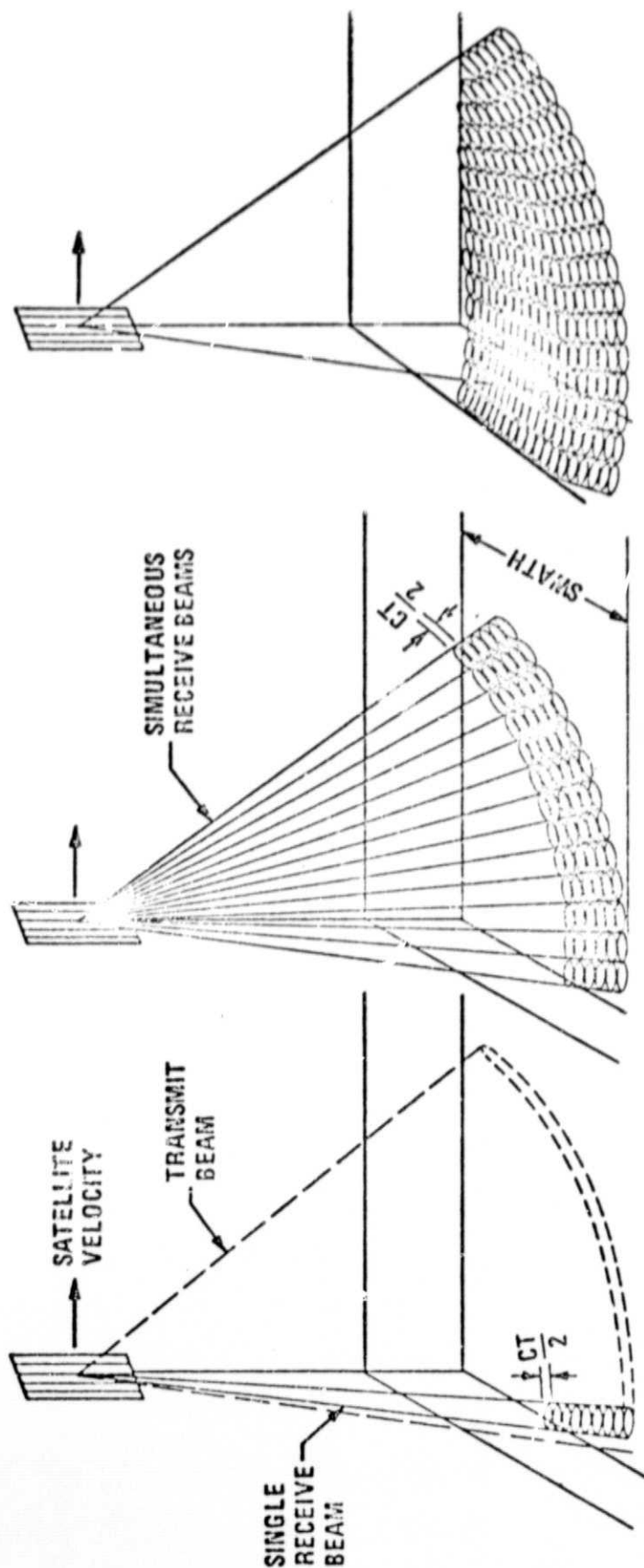
TABLE 6
METEOROLOGICAL RADAR

Experimenter: J. Eckerman

- A. OBJECTIVE: Develop spaceborne meteorological radar for global 3-dimensional mapping of precipitation over land and sea.
- B. NEED: To support NASA missions with weather prediction, weather danger and disaster warnings, and understanding of storm processes and mechanics.
- C. EXPERIMENTAL TECHNIQUE:
1. High resolution 3-dimensional mapping of storms.
 2. Pulse and Doppler processing, synthetic azimuth processing.
 3. Large swath width.
 4. 4m x 5m X-band array.
 5. Multiple, simultaneous, fixed beams.

FIGURE 1

3-D STORM MAPPING BY MULTIPLE BEAM RADAR



EACH BEAM GENERATES COLUMN OF RANGE CELLS

(A)

MULTIPLE BEAMS GENERATE SHEET OF RANGE CELLS

(B)

SPACE CRAFT MOVEMENT GENERATES VOLUME OF RANGE CELLS — "PUSH BROOM"

(C)

TABLE 7

SURFACE SPECTRUM RADAR EXPERIMENT

Experimenter: T. Walton

- A. OBJECTIVE: Provide information on sea state, sea ice, soil moisture, hydrology, agriculture, and geophysics.
- B. NEED: To provide greater maritime safety, and improve economics of land use.
- C. EXPERIMENTAL TECHNIQUE:
1. Short pulse chirped radar at 10 GHz.
 2. Sea wave spectra taken over conical scan.
 3. Land/ice spectra combined with radiometer data.

FIGURE 2
SURFACE SPECTRUM RADAR EXPERIMENT
OCEANOGRAPHIC MISSION

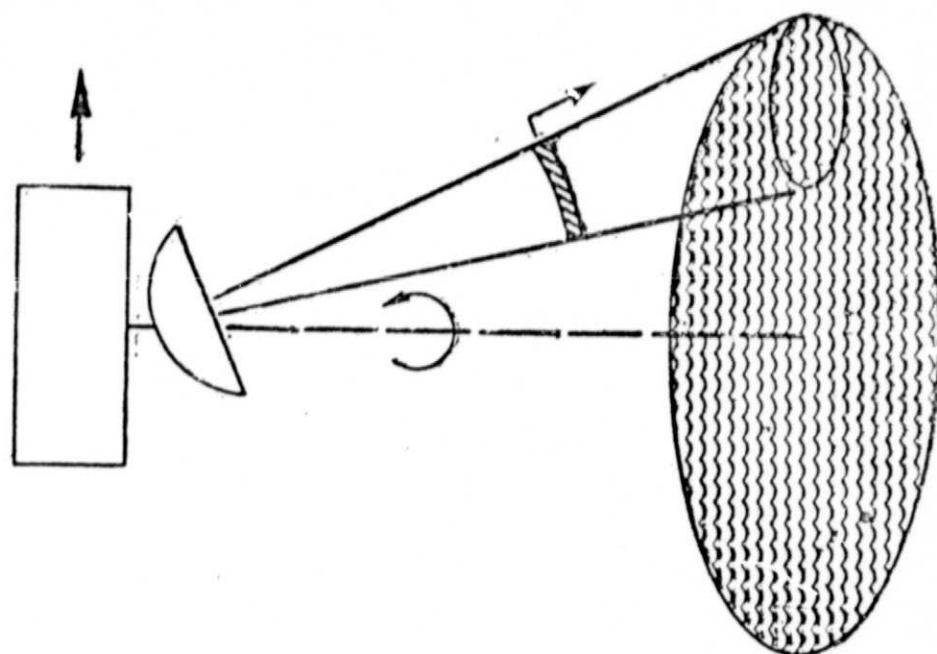


TABLE 8

ATMOSPHERIC AND OCEANOGRAPHIC IMAGING RADIOMETER EXPERIMENT

Experimenter: J. C. Shiue

- A. OBJECTIVE: To provide precipitation, water vapor, and sea state data and correlate with meteorological radar's precipitation mapping experiment.
- B. NEED: Improve weather prediction and contribute to coastal process, fishery and climatology studies.
- C. EXPERIMENTAL TECHNIQUE:
1. Radiometers at 18 and 22 GHz.
 2. 1.5m dish with low sidelobe characteristics for high resolution.
 3. Plane or conical scan for coverage of wide areas.

TABLE 9

SOIL MOISTURE AND SALINITY RADIOMETER EXPERIMENT

Experimenter: J. C. Shiue

- A. OBJECTIVE: To provide high resolution measurements of soil moisture over land and salinity over sea water.
- B. NEED: To improve crop yield, predict flooding, and improve water resource management and to contribute to coastal process studies.

C. EXPERIMENTAL TECHNIQUE:

- 1. Radiometer at 1.4 GHz.
- 2. 3m x 3m array to provide high resolution.
- 3. Low sidelobe antenna.
- 4. Plane scan for a coverage of wide areas.

TABLE 10

ANTENNA RANGE EXPERIMENT

Experimenter: R. Taylor

A. OBJECTIVE: To provide an in-orbit far-field RF signal source for gain and pattern measurements of ground based antennas.

B. NEED: To provide a means of accurately measuring the characteristics of very large steerable antennas.

C. EXPERIMENTAL TECHNIQUE:

1. Low power transmitters.
2. May use EEE flight hardware.
3. Several standard frequencies.

TABLE 11

DATA COLLECTION WITH MULTIBEAM

Experimenter: L. Ded

A. OBJECTIVE: To demonstrate and develop a technique to increase sensitivity and channel capacity of a Data Collection System.

B. NEED: Provide low-cost Data Collection System.

C. EXPERIMENTAL TECHNIQUE:

1. 400 MHz multiple-beam antenna system.
2. Large number of narrow beams.
3. Large array antenna.
4. Random access earth stations.

TABLE 12
COOPERATIVE SURVEILLANCE BY SPACELAB RADAR

Experimenter: L. Roach

- A. OBJECTIVE: Demonstrate & evaluate the technology applicable to the following U. S. Coast Guard missions:
- Law enforcement
 - Navigation
 - Search & rescue.
- B. NEED: Reliable and economical method of surveillance, detection, identification and location.
- C. EXPERIMENTAL TECHNIQUE:
1. Users marked by coded radar repeaters.
 2. Uses synthetic radar to observe users.
 3. Shares meteorological radar facility.

TABLE 13

NAVSTAR/GPS

Experimenter: J. Turkiewicz

- A. OBJECTIVE: To evaluate GPS as a basic navigation technique for future spacecraft.
- B. NEED: As an alternative to star trackers, the GPS may provide navigation correction without interruption of earth orientated measurements.
- C. EXPERIMENTAL TECHNIQUE:
1. L-band antenna receives NAVSTAR signals.
 2. Processor determines attitude and position to update IMU.

2. ANTENNA DESCRIPTIONS

2.1 INTRODUCTION

The MMAP contains fourteen antenna sets shared by the experiments. In the present concept these antennas are mounted together in three groupings. They are: (a) the upper antenna cluster, (b) the lower antenna cluster and (c) the NAVSTAR/GPS antenna. The NAVSTAR/GPS antenna is mounted to the Spacelab on an extendable boom to view NAVSTAR satellites in high altitude orbits.

This section of the report will describe the upper and lower antenna clusters, antenna mounting in the Spacelab and weight and center-of-gravity estimates.

2.2 UPPER ANTENNA CLUSTER

The upper antenna cluster is illustrated in Figure 3 and contains nine antennas which are listed in Table 14. The 3m x 3m array operates from 0.4 to 0.5 GHz and consists of crossed dipoles with a manifold feed to form multiple beams. This antenna will be used by the Electro-magnetic Environment Experiment (EEE) and Data Collection with Multi-Beam (DCM) Experiments and will have several operational modes. One will be the formation of a number of narrow beams to be used for the DCM Experiment, another is a monopulse mode to be used for the EEE. The array will have both orthogonal linear polarization and right-hand circular polarization capabilities.

FIGURE 3
MMAP UPPER ANTENNA CLUSTER

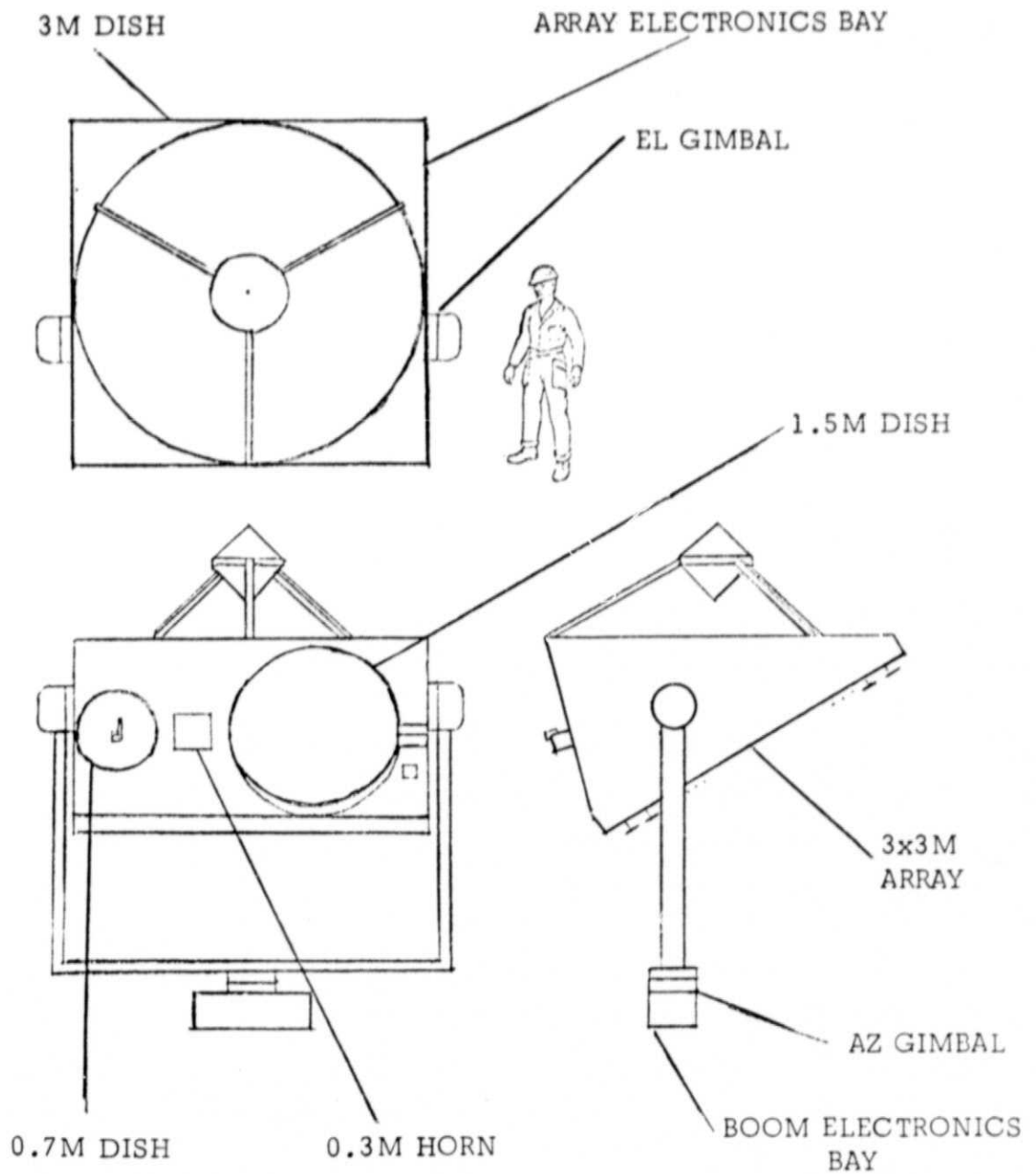


TABLE 14
UPPER ANTENNA CLUSTER

<u>Antenna No.</u>	<u>Frequency (GHz)</u>	<u>Description</u>
1	0.4-0.5	3x3m array of crossed dipoles with monopulse manifold feed
2	1.4	3x3m array interleaved with antenna #1, radiator types TBD
3	1-12	3m dish with LP monopulse feed
4	1-12	LP monopulse antennas
5	12-26	1.5m dish with off-set corrugated horn
6	12-26	Corrugated horn
7	26-40	0.7m dish with W/G horn feed
8	26-40	W/G horn
9	40-100	0.3m horn

Interleaved with the elements of the 3m x 3m array are elements of a sub-array operating at 1.4 GHz. This sub-array will be used by the Soil Moisture and Salinity Radiometer to obtain a high efficiency beam ($\sim 85\%$). A beamwidth of about 5° is required by this experiment and results in a footprint diameter of 35 km at nadir.

Connected to the back of the 3m x 3m aperture is a 3m dish to be used by the EEE and Antenna Range Experiments. This dish is fed by a log periodic monopulse antenna operating from 1 to 12 GHz with a beamwidth of 1.7° to 7° . In addition, a similar log periodic antenna pointing directly toward the earth will provide wide beam coverage in this band.

A 1.5m diameter dish will be shared by the EEE and the Atmospheric and Oceanographic Imaging Radiometer. This dish operates from 12 to 26 GHz and is fed by an offset corrugated horn to provide a beamwidth of 0.5° to 0.7° with 95% efficiency. A similar corrugated horn will point directly toward earth to provide wide beam coverage at Ku- and K-bands.

A 0.7m diameter dish, fed by a waveguide horn operating from 26 to 40 GHz, will be used by the EEE and the Millimeter Wave Communications Experiment. A similar waveguide horn, operating in the same band, will provide a wide angle view. Finally, a 0.3m horn will provide frequency coverage from 40 to 100 GHz.

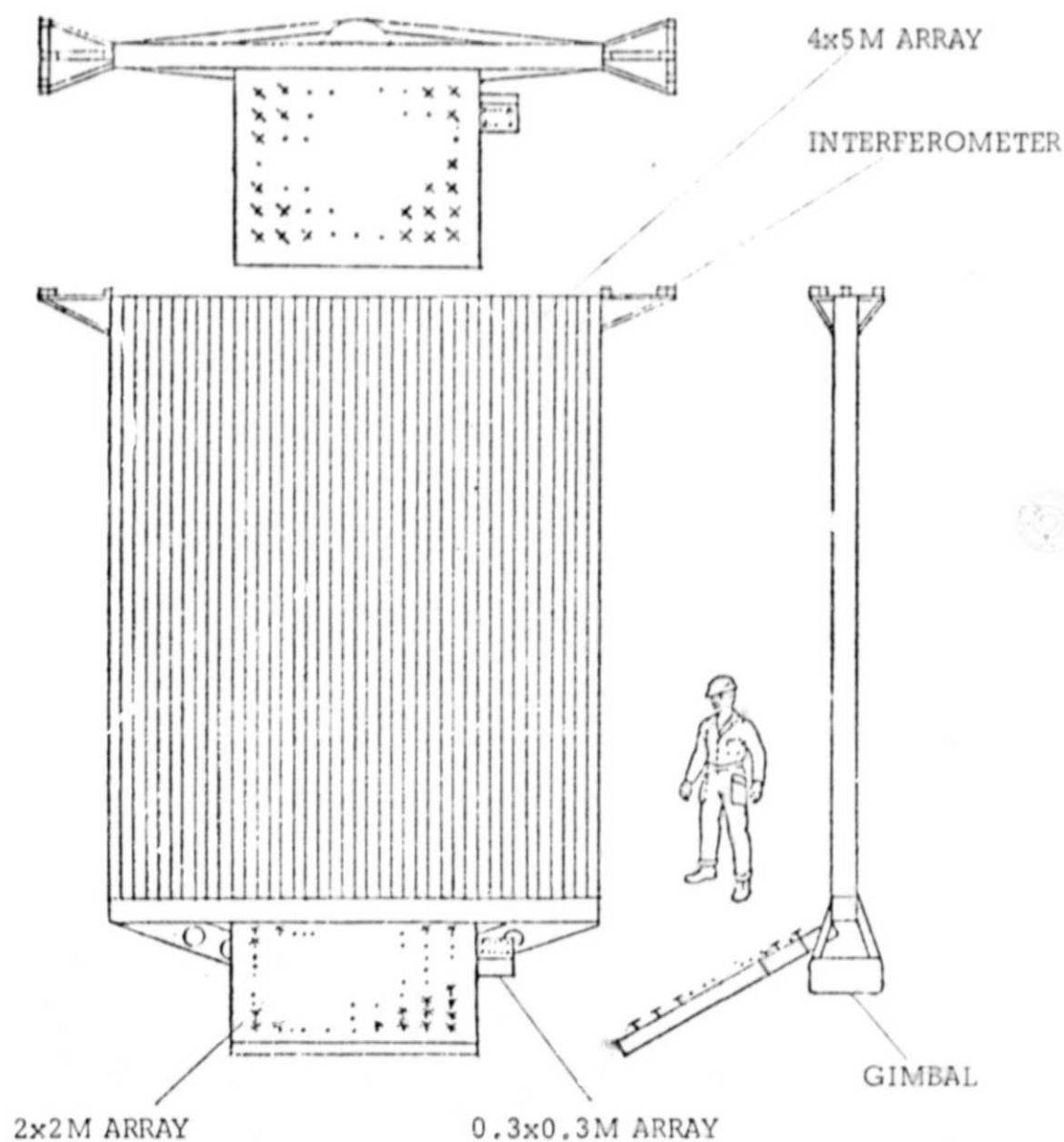
These antennas are mounted together with an electronics bay containing down-converters, amplifiers and switches. This entire assembly is mounted on a set of two-axis gimbals with either rotary joints or flexible joints at the azimuth and elevation rotation points. Elevation must be variable over $\pm 180^\circ$ so that each antenna in the cluster can be brought into position. Azimuth is continuously variable over 360° . The azimuth gimbal is mounted on an electronics bay which contains transmitter power amplifiers and additional down-converters and amplifiers. The electronics are described in greater detail in Section 3.

2.3 LOWER ANTENNA CLUSTER

The lower antenna cluster is composed of a 4m x 5m aperture, a 2m x 2m array, a 0.3m x 0.3m array, and an X-band interferometer. This concept is shown in Figure 4. The 4m x 5m aperture will be used by the Meteorological (Met) Radar, Surface Radar, and Cooperative Surveillance Experiments. This aperture operates at X-band and is composed of interleaved transmitting and receiving sections.

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FIGURE 4
MMAF LOWER ANTENNA CLUSTER



A 2m x 2m electronically steered array, operating at L-band, and a 0.3m x 0.3m array, operating at X-band, is mounted to the bottom of this aperture. An X-band interferometer, which will provide accurate position and attitude information for the Met Radar, is placed at the top of the 4m x 5m aperture.

This lower cluster contains an electronics bay and is mounted on an azimuth gimbal. When the Met Radar is being used, the cluster will be oriented with the 4m x 5m aperture in the plane of the tail of the Orbiter so that near-field interference will be minimized. This will require that the Orbiter fly with a 45° yaw angle with respect to the velocity vector to provide the proper ground footprint. The 4m x 5m aperture will be rotated to provide a conical or partial-conical scan pattern when the Surface Radar is operated. The mechanical azimuth steering will also increase the flexibility of the Cooperative Surveillance and the Adaptive Multi-Beam Antenna Experiments. The utilization of each antenna is summarized in Table 15.

2.4 PHYSICAL CONFIGURATION

Figure 5 shows the MMAP mounted in the Spacelab with the antennas in the deployed position. Spacelab equipment shown consists of three 3-meter pallets and a short pressurized module although other concepts, including some without a pressurized module, are being considered. In this concept, the upper antenna cluster is located on top of the lower antenna cluster so that Orbiter tail obstruction of beams from the upper antenna cluster is minimized. Some obstruction of the lower antenna cluster occurs, but this is of minor importance. Of greater concern, however, is near-field interference of the lower antenna cluster from the tail and from the pressurized module. This interference may be minimized by locating the base of this lower cluster near the center of the three pallets.

In stowed position, the base of the lower cluster must be moved toward the aft end of the bay as the antennas are folded, as shown in Figure 6. The deployment sequence consists of first partially rotating the upper/lower cluster assembly, then sliding the base of the lower antenna cluster forward on a track. This is followed by complete rotation of the upper/lower cluster assembly to a vertical position and raising the antennas above the pallets. Finally, the 2m x 2m and 0.3m x 0.3m arrays are unfolded and the NAVSTAR/GPS booms raised and extended.

TABLE 15

ANTENNA UTILIZATION

<u>Antenna</u>	<u>Steering</u>	<u>Frequency (GHz)</u>	<u>Experiment</u>	<u>Receive</u>	<u>Transmit</u>
0.3M Horn	Mech	40-100	EEE	X	
0.7M Dish	Mech	26-40	EEE	X	
		30	MMWC	X	
1.5M Dish	Mech	12-26	EEE	X	
		18 & 22	S&O R/M	X	
3.0M Dish	Mech	1-12	EEE	X	X
		1.5, 4, 10	ARE		
0.3M x 0.3M Array	Elec	10	AMBA	X	X
2 x 2M Array	Elec	1.5	AMBA	X	X
3 x 3M Array	Mech	0.4-0.5	EEE	X	
		0.5	ARE		X
		1.4	SMS R/M	X	
		0.4	MBDC	X	
4 x 5M Array	Mech	10	METRAD	X	X
		10	SUR RAD	X	X
		10	CSSR	X	X
0.7M I/F Array	Fixed	10	I/F	X	
Stub	Fixed	1.2	NAVSTAR/GPS	X	

FIGURE 5
MMAP ANTENNA ARRANGEMENT - DEPLOYED

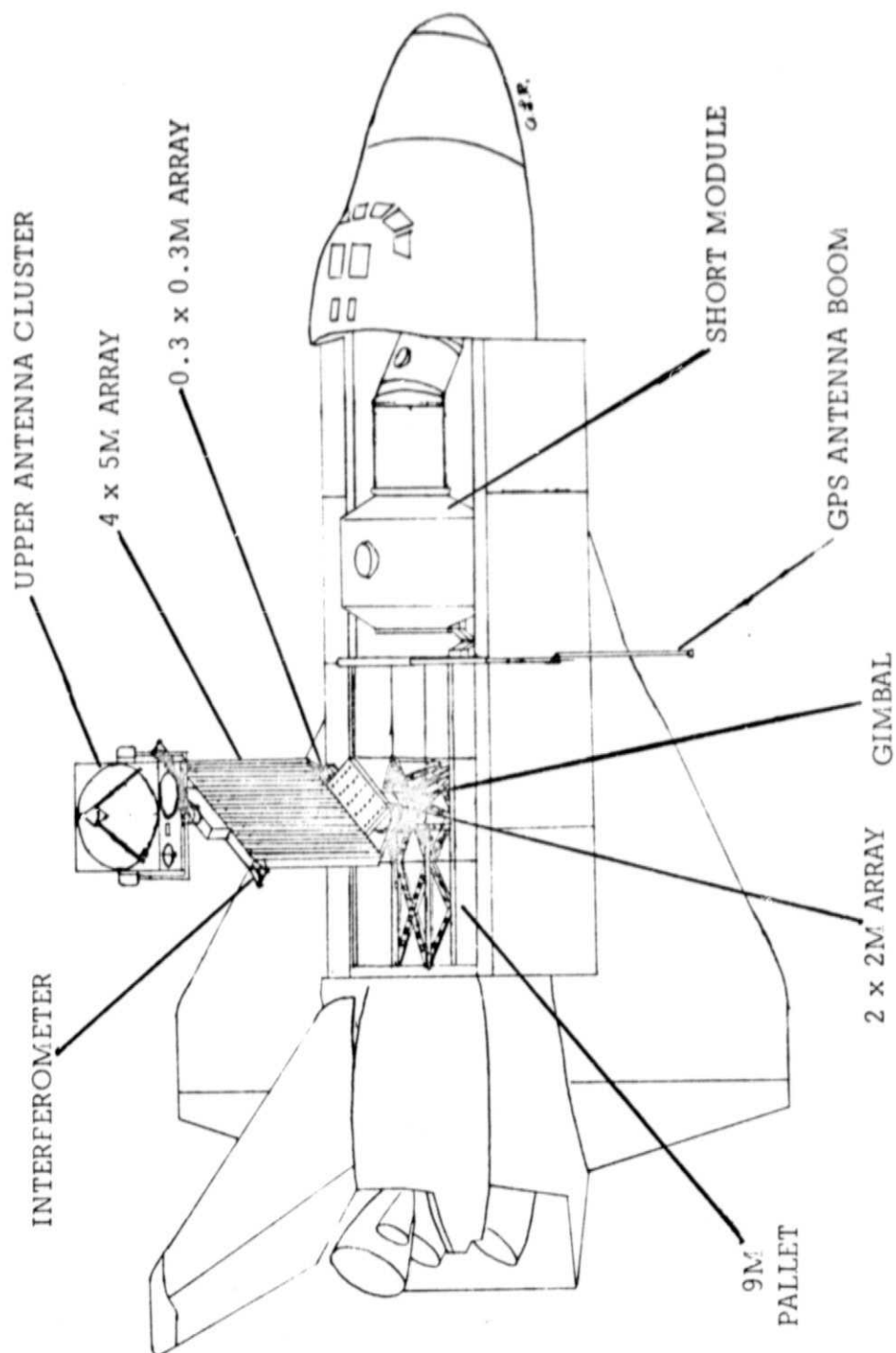
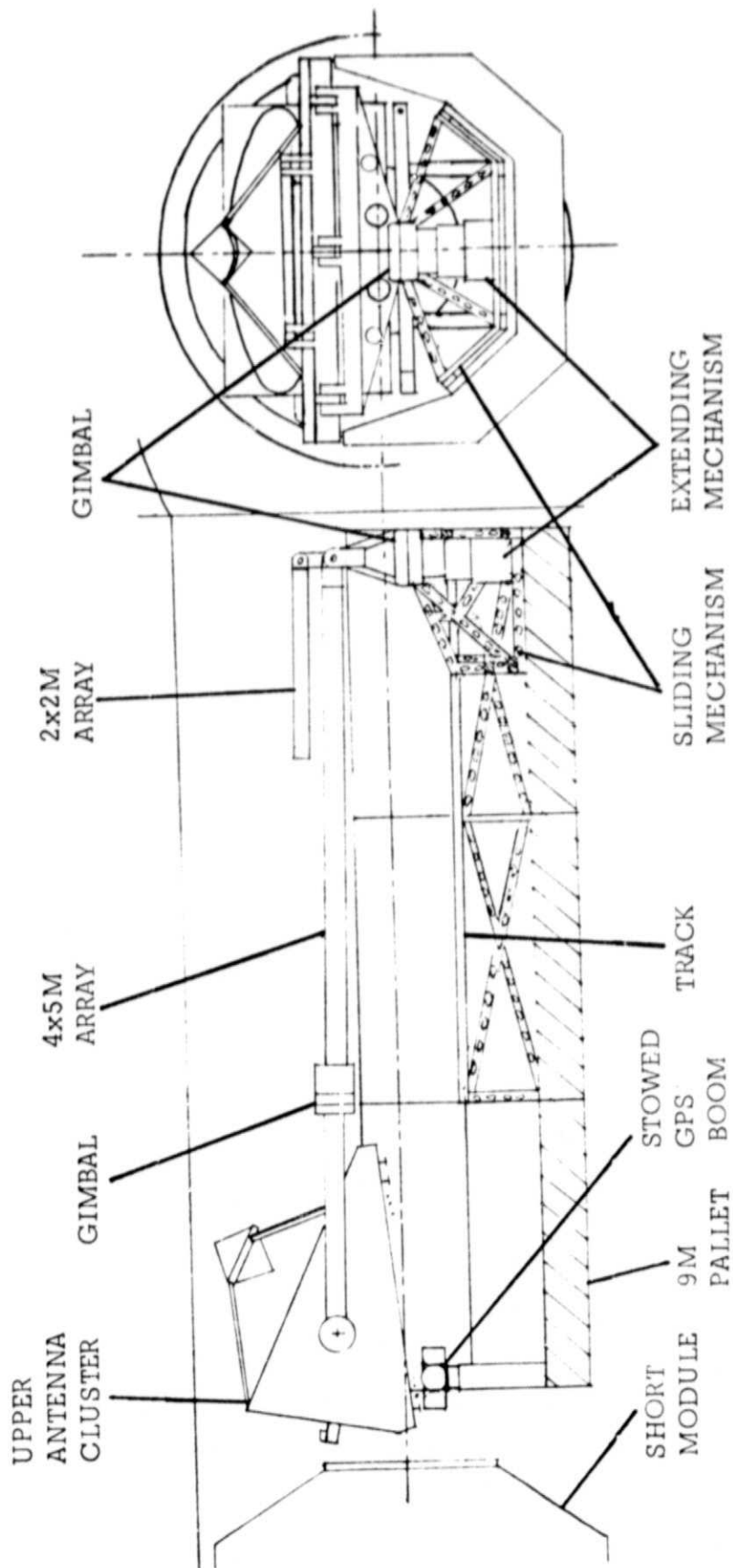


FIGURE 6

MMAP ANTENNA ARRANGEMENT - STOWED



2.5 WEIGHT AND CENTER-OF-GRAVITY

Estimates of the weights of the components of MMAP are shown in Table 16. These weights are very tentative and have been computed to give an estimate of the center-of-gravity (c.g.). The c.g. position is very critical and must be carefully considered in planning the payload configuration. Figure 7 shows the area in c.g. - weight space which would contain any point generated as the weights are allowed to vary $\pm 50\%$ from the estimates given in Table 16 (the positions are assumed fixed). It will be noted from Figure 8 that this area is within the area which may be accommodated by either a three pallet-short module Spacelab arrangement or a five pallet arrangement.

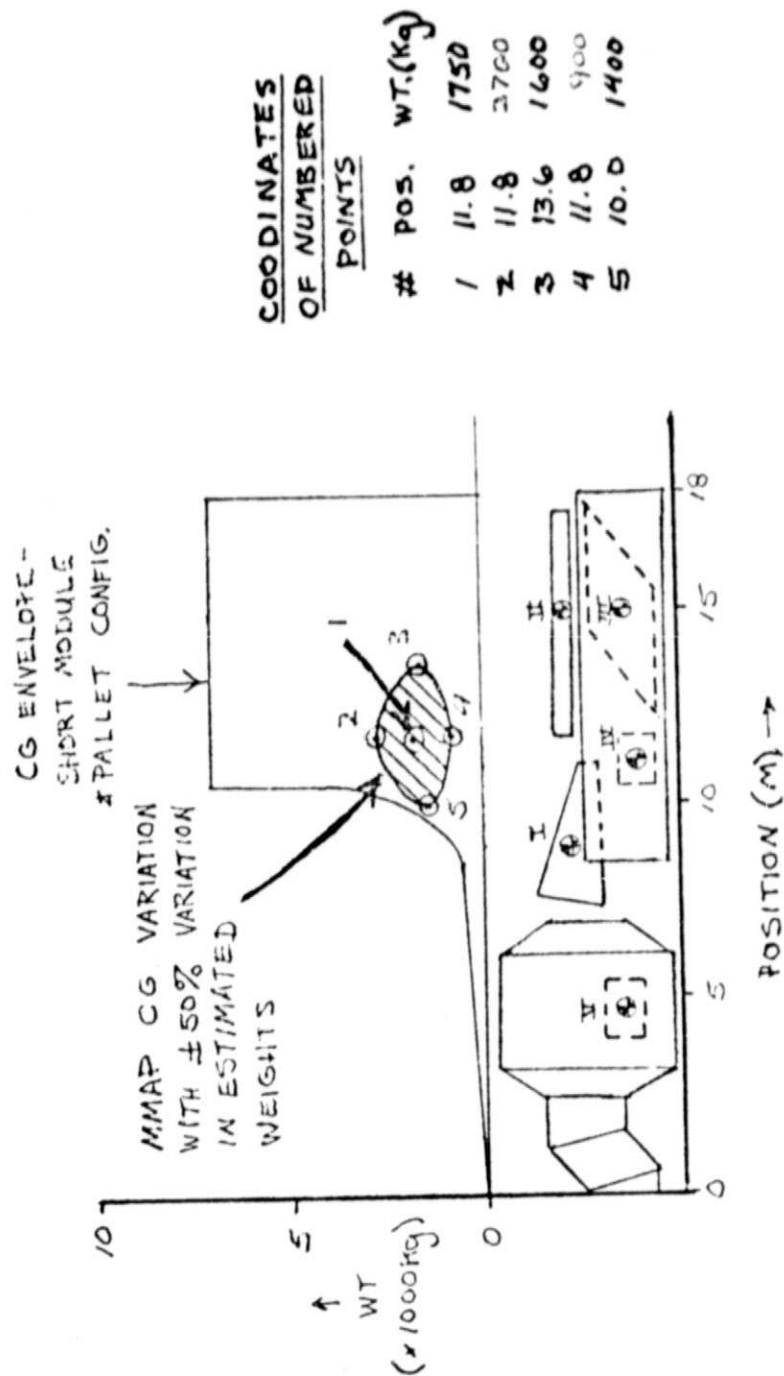
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TABLE 16

MMAP WEIGHT ESTIMATES

I. Upper Antenna Set	Weight (lbs)	Weight (lbs) (Kg)	CG Position (m) (Ref. from forward and cargo bay)
1. 3m Dish	50		
2. 1.5m Dish	30		
3. 0.7m Dish	10		
4. 3 x 3m Array	125		
5. Gimbals	100		
6. Electronics & Other Ant.	300		
7. Structure & Misc.	<u>300</u>		
Sub-total	(915)	900 400	10.4
II. Lower Antenna Set			
1. 4 x 5m Array	800		
2. 2 x 2m Array	50		
3. 0.3 x 0.3m Array	25		
4. Structure	200		
5. Gimbal	<u>100</u>		
Sub-total	(1085)	1000 450	16.0
III. Antenna Deployment Structure (~1/4 Antenna Weight)		500 225	16.0
IV. Pallet Mounted Electronics		500 225	12.0
V. Module Mounted Electronics		<u>1000</u> <u>450</u>	<u>6.6</u>
Total Weights		3900 1750	
Total CG Position			11.8

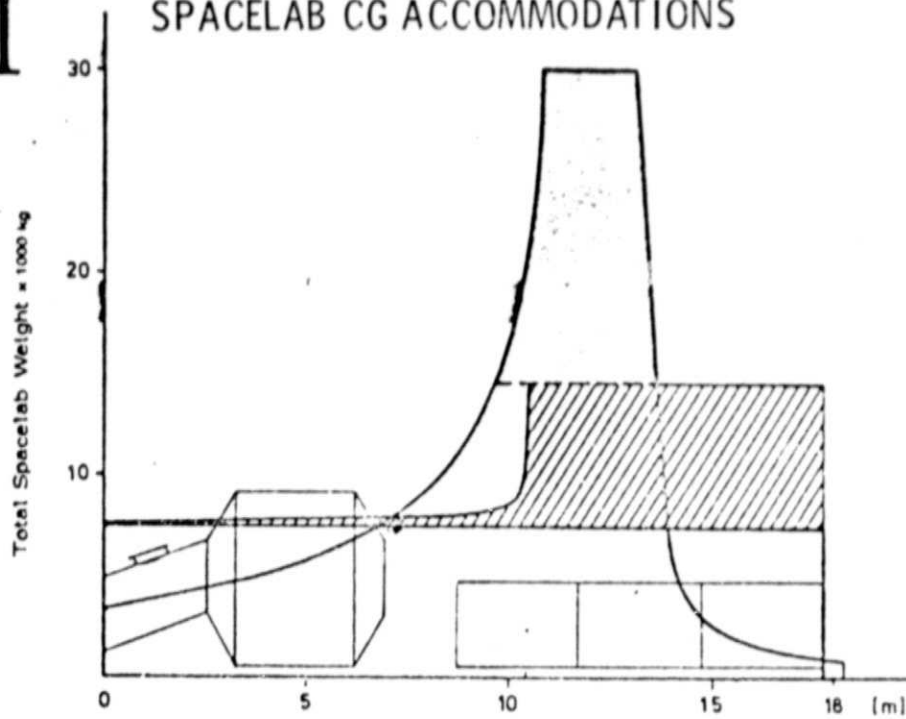
FIGURE 7
MMA CG ESTIMATE



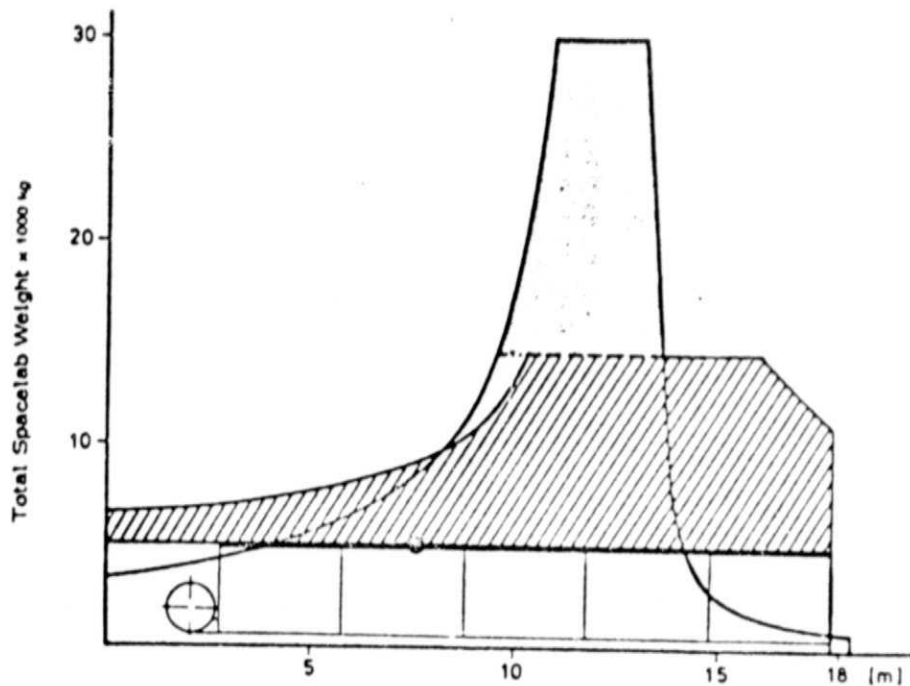
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FIGURE 8

SPACELAB CG ACCOMMODATIONS



CG Envelope - Short Module & Pallet Configuration



15 Meter Pallet Configuration

From Spacelab
Accommodation
Handbook 10/74

3. ELECTRONICS

3.1 INTRODUCTION

Most of the MMAP electronics equipment is used by more than one experiment. Each experiment generally will have a dedicated signal processor, however. To date this study has concentrated on the antenna electronics requirements although concepts of the general electronics equipment requirements have been considered. This section of the report will discuss the electronics mounted in the antennas and, in less detail, the electronics which will be mounted on the pallets or in the pressurized module.

3.2 ANTENNA ELECTRONICS

A block diagram of the antenna electronics required for MMAP is shown in Figure 9. The upper antenna bay contains the upper antenna cluster apertures, low-noise amplifiers, down-converters, IF amplifiers, switch networks, and frequency synthesizers. The weight of this equipment should be minimized to meet requirements for rapid antenna scan. Since the down-converters and switches decrease the number of channels carrying information from the antenna cluster to the pallet, this minimum weight requirement must be traded-off with the necessity of minimizing the complexity of the azimuth and elevation rotary joints. The rotary joints must also carry reference RF signals for the generation of local oscillator signals in the upper antenna bay and various data, power, and telemetry signals to control and energize equipment in the bay. Moderate transmitter power is also transferred through the rotary joints for use in the Antenna Range Experiment (ARE). These rotary joints require careful study.

Below the upper antenna cluster is another electronics bay which contains other down-converters and amplifiers which may be necessary to overcome rather large cable losses between the antennas and the pallet. Frequency synthesizers and RF power amplifiers will also be located in this bay.

FIGURE 9
MMAP ANTENNA BLOCK DIAGRAM



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The electronics systems associated with the L-band 2m x 2m array and the X-band 0.3m x 0.3m array are similar. These systems consist of the antenna elements connected to sets of phase shifters which are driven by pointing control systems. The phase shifters may be used to steer the beams both on receive and transmit, although further study of this concept is required. The phase-shifters are connected to a set of duplexers. The transmit signals are derived from a set of variable gain amplifiers, driven by a power taper control. The inputs to these amplifiers are provided from a common power source through power dividers. A pre-amplifier is mounted on the pallet.

The receive outputs of the duplexers are fed into a set of down-converters and IF amplifiers. IF PIN-diode attenuators allow power tapering of the receive beam. These outputs are then summed and the IF's from the two arrays are then combined for common signal processing.

The outputs of the 4m x 5m receive array are fed into a Butler matrix to form a series of beams. The output from each beam is then down-converted and amplified. Because of the large number of beams, some signal processing may be required at the antenna to minimize the number of signals through the lower azimuth rotary joint (#1). The transmit array is driven by a power divider and a power amplifier (P.A.) mounted at the array. This P.A. must be near the aperture to compensate for cable losses.

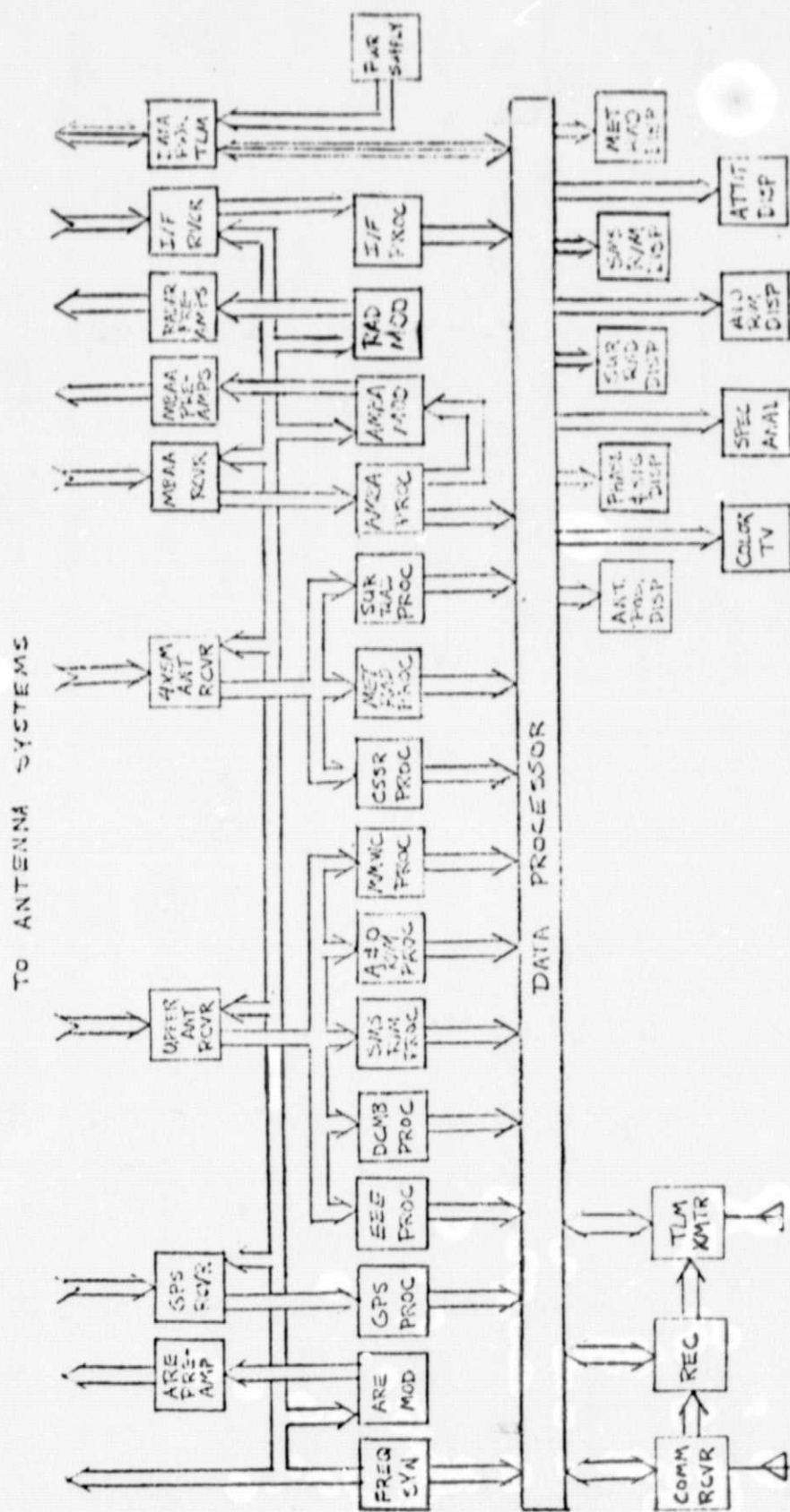
3.3 SYSTEM BLOCK DIAGRAM

The MMAP Systems Block Diagram is shown in Figure 10. A central frequency synthesizer provides reference signals to the antenna synthesizers while other outputs are used as local oscillators for the four receivers and as reference signals for up-converters and modulators. This synthesizer also provides timing reference to the data processor. The upper antenna receiver is shared by five experiments: the Soil Moisture and Salinity Radiometer, Atmospheric and Oceanographic Imaging Radiometer, Millimeter Wave Communications, Electromagnetic Environment, and Data Collection with Multi-Beam Experiments, each of which has its own processor. The 4m x 5m array receiver is shared by four experiments which each have their own processors. These experiments are the Met Radar, Surface Spectrum Radar, and Cooperative Surveillance Experiments.

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FIGURE 10

MMAP SYSTEMS BLOCK DIAGRAM



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The Adaptive Multi-Beam Antenna Experiment (AMBA) receiver output goes to the AMBA processor which samples the system operation and transfers information to the AMBA modulator. The modulator output is pre-amplified on the pallet and transmitted to the AMBA antennas. The radar modulator drives the radar pre-amplifiers which feed the 4m x 5m transmitter antenna for the Met and Surface Spectrum Radars. The Attitude/Position Interferometer and NAVSTAR/GSP Experiments have dedicated receivers and processors, although further study may indicate that these systems may be combined.

The outputs of the signal processors are transferred to a common data processor. This data processor also receives inputs from the command receiver and possibly a tape recorder. Data outputs are to the recorder and telemetry transmitter as well as to a variety of display equipment.

4. MMAP OPERATIONS

4.1 ORBITS AND OBSERVATION TIMES

Table 17 indicates various parameters which are useful in developing specifications for the MMAP antenna and experiment requirements. Figure 11 shows the antenna pointing angle required to track a fixed ground target, on Orbiter ground track, as a function of time. At time $t = 0$, the Orbiter is directly above the target and at the dashed line the Orbiter passes over the horizon. This data is utilized in Figure 12 to determine the maximum observation time of a fixed target for an antenna with limited pointing angle. This figure indicates that antennas of small maximum pointing angle have very short observation time; for example, at a 400 km orbit, an antenna with $\pm 25^\circ$ maximum pointing angle can track a ground target for 40 seconds.

4.2 ESTIMATED EXPERIMENT TIME USE

Table 18 summarizes the estimated experiment time use. Experiments which operate for short periods of time are limited by either beam size or by maximum pointing angle. Experiments conducted over the United States will be able to make observations for 10 to 20 minutes per orbit. More study is required to determine orbital timelines and their impact upon equipment requirements.

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TABLE 17
ORBITAL PARAMETERS

Altitude (km)	Orbital Period (min)	Horizon Angle, ϕ ($^\circ$)	Time of Travel Horiz-Horiz (min)	Ground Distance Horiz-Horiz (km)	Scan Angle Rate Near Nadir ($\dot{\phi}$) ($^\circ$ /Sec)
200	86.0	75.9	6.74	3,140	2.23
400	87.2	70.3	9.54	4,400	1.10
600	88.5	66.1	11.76	5,340	0.73

FIGURE 11

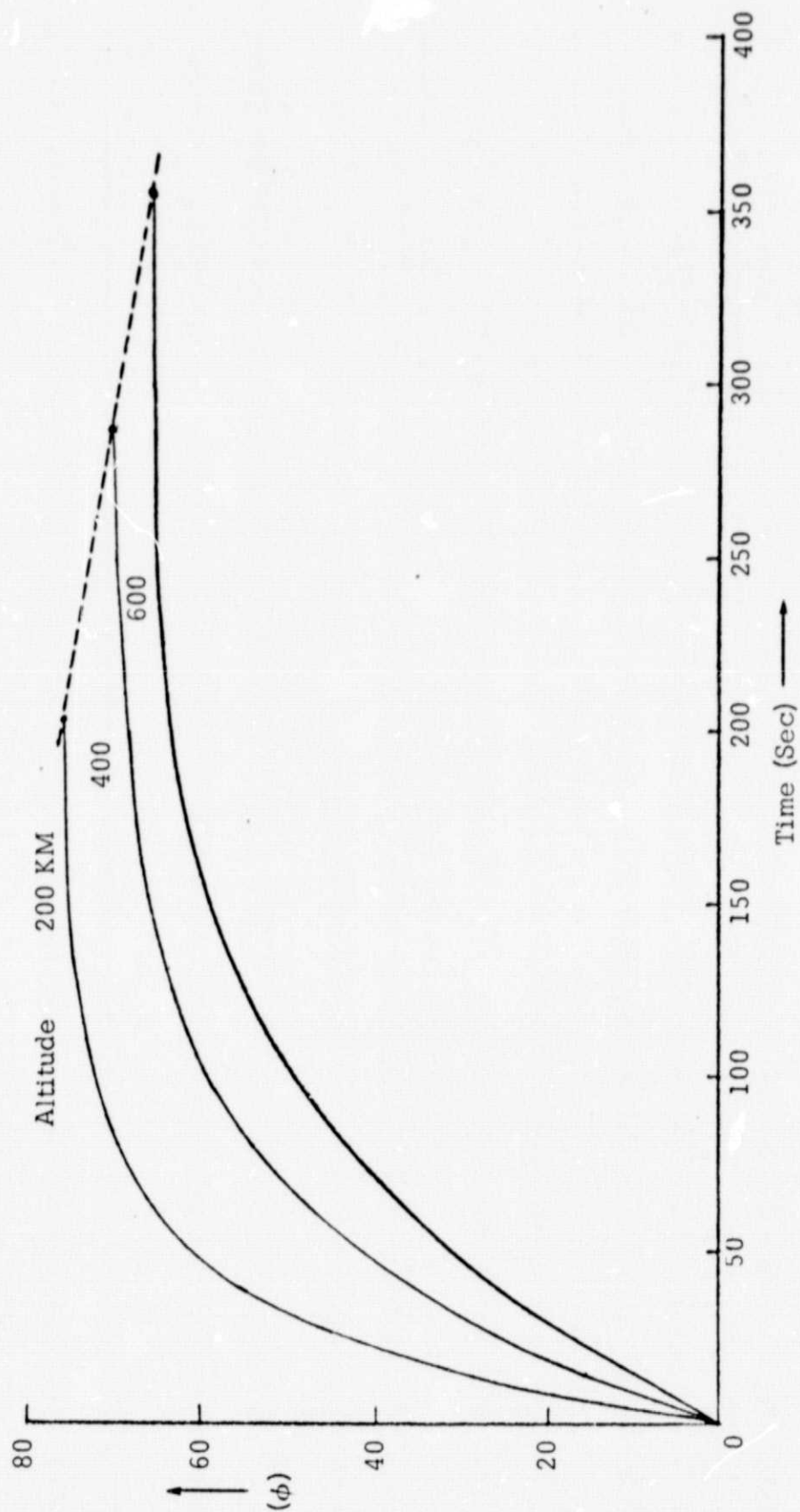
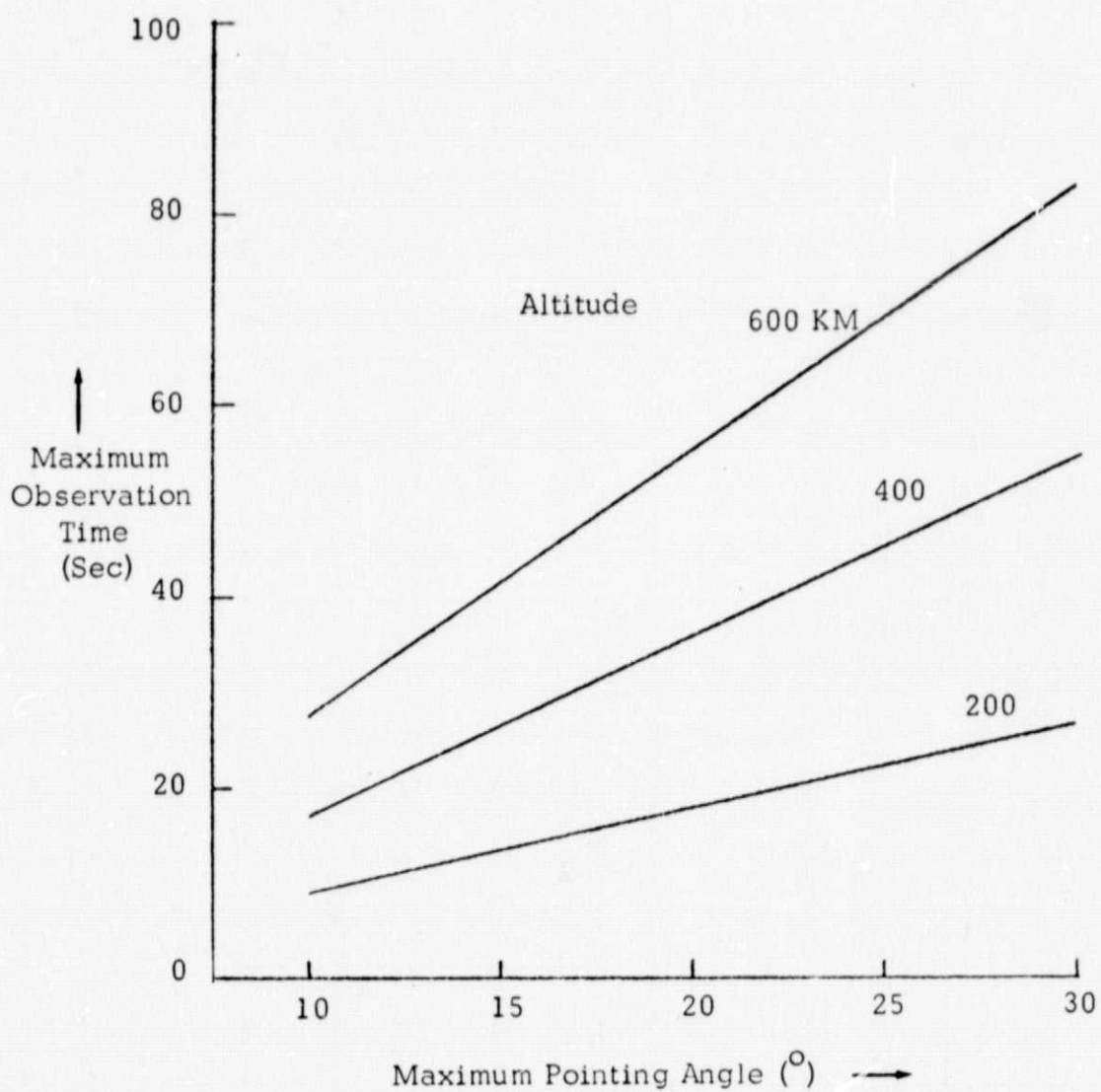
POINTING ANGLE TO A FIXED TARGET (ϕ) VS. TIME

FIGURE 12
MAXIMUM OBSERVATION TIME VS.
MAXIMUM ANTENNA POINTING ANGLE



ESTIMATED EXPERIMENT TIME USE

EEE -	MAINLY OVER U.S. (≈ 20 MIN / ORBIT OVER U.S.)
MMWC -	WHEN USER STATION IS IN VIEW (≈ 10 MIN / ORBIT OVER U.S.)
AMBA -	WHEN TWO STATIONS ARE IN VIEW (≈ 1 MIN / ORBIT OVER U.S.)
I/F -	WHEN TWO STATIONS ARE IN VIEW (≈ 1 MIN / ORBIT OVER U.S.)
METRAD -	MAINLY OVER U.S. AND HURRICANE / TYPHOON AREAS (≈ 30 MIN / ORBIT)
SUR RAD -	OVER OCEANS (≈ 60 MIN / ORBIT) AND LAND AREAS (≈ 30 MIN / ORBIT)
A&O R / M -	OVER OCEANS AND LAND (SAME TIME AS METRAD)
SMS R / M -	MAINLY OVER LAND AND COAST (≈ 10 MIN / ORBIT OVER U.S.)
ARE -	WHEN USER IS IN VIEW (≈ 10 MIN / ORBIT OVER U.S.)
DCMB -	OVER U.S. (≈ 20 MIN / ORBIT OVER U.S.)
CSSR -	OVER OR NEAR U.S. (≈ 20 MIN / ORBIT OVER U.S.)
GPS -	LIMITED ONLY BY GPS STATUS

5. MMAP TASK DESCRIPTION AND SCHEDULE

Table 19 summarizes the initial tasks which must be considered in the near future. To date, items 1 through 2.a have been examined to some depth. Figure 13 illustrates the major tasks which must be carried out during the time period 1975 through 1981, assuming a 1981 launch. Figure 14 shows the schedule required over the period from July 1975 through September 1976 to define the MMAP mission. Finally, Figure 15 illustrates the tasks which must be carried out immediately to define a strawman payload.

TABLE 19
INITIAL PAYLOAD DEFINITION TASKS

1. PRELIMINARY DEFINITION
2. EQUIPMENT SHARING TRADE-OFF STUDY
 - a. ANTENNAS
 - b. TIME-SHARING
 - c. TRANSMITTERS AND RECEIVERS
 - d. SIGNAL PROCESSING
 - e. DATA RATES AND PROCESSING
3. FIRST DEFINITION REFINEMENT

TABLE 19
INITIAL PAYLOAD DEFINITION TASKS (CONT)

- 4. PAYLOAD TRADE-OFF STUDY
 - a. POWER
 - b. CRUDE MECHANICAL CONFIGURATION
 - c. THERMAL
 - d. WEIGHT
 - e. EQUIPMENT SHARING REFINEMENTS
- 5. SECOND DEFINITION REFINEMENT

FIGURE 13

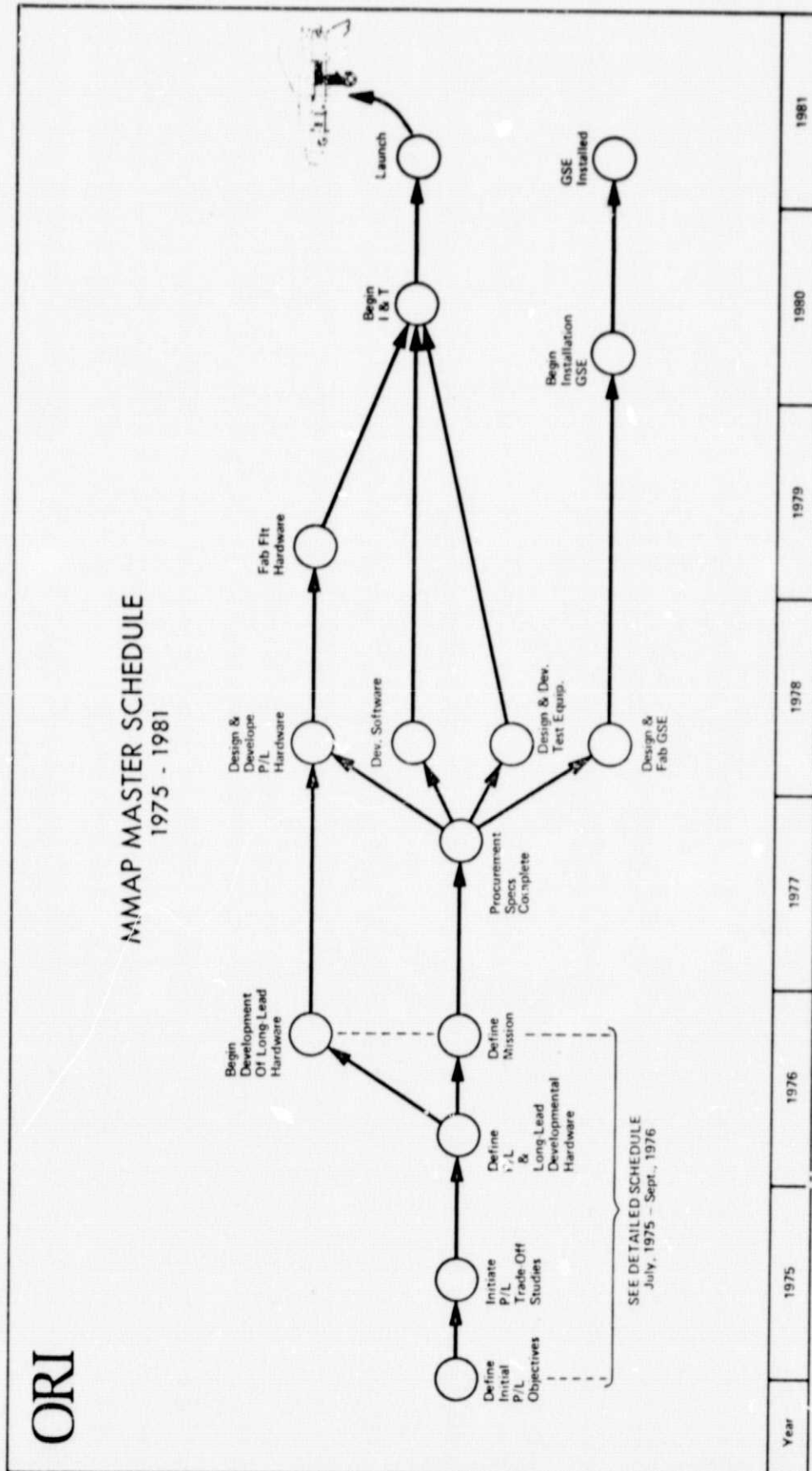


FIGURE 14

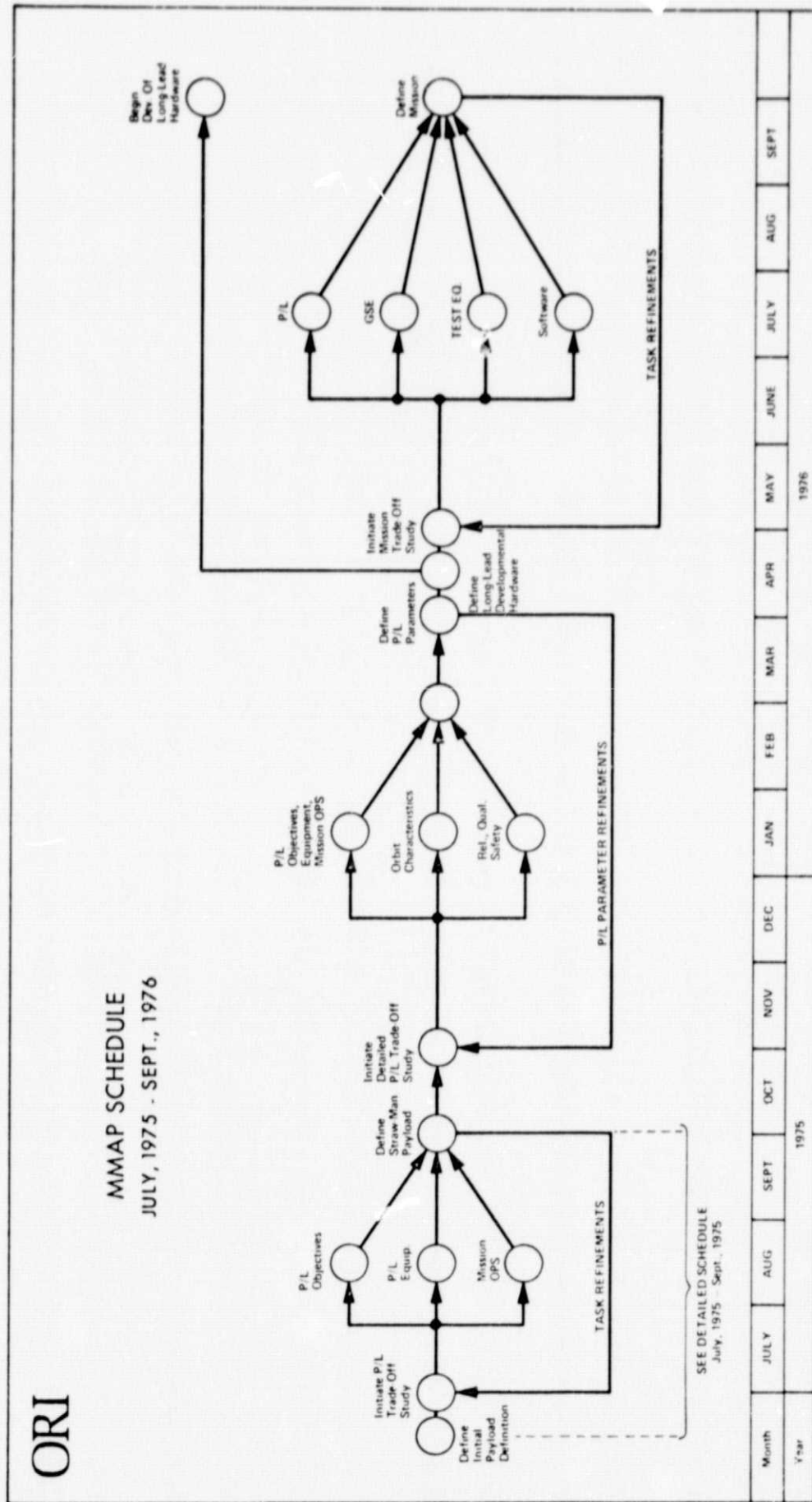
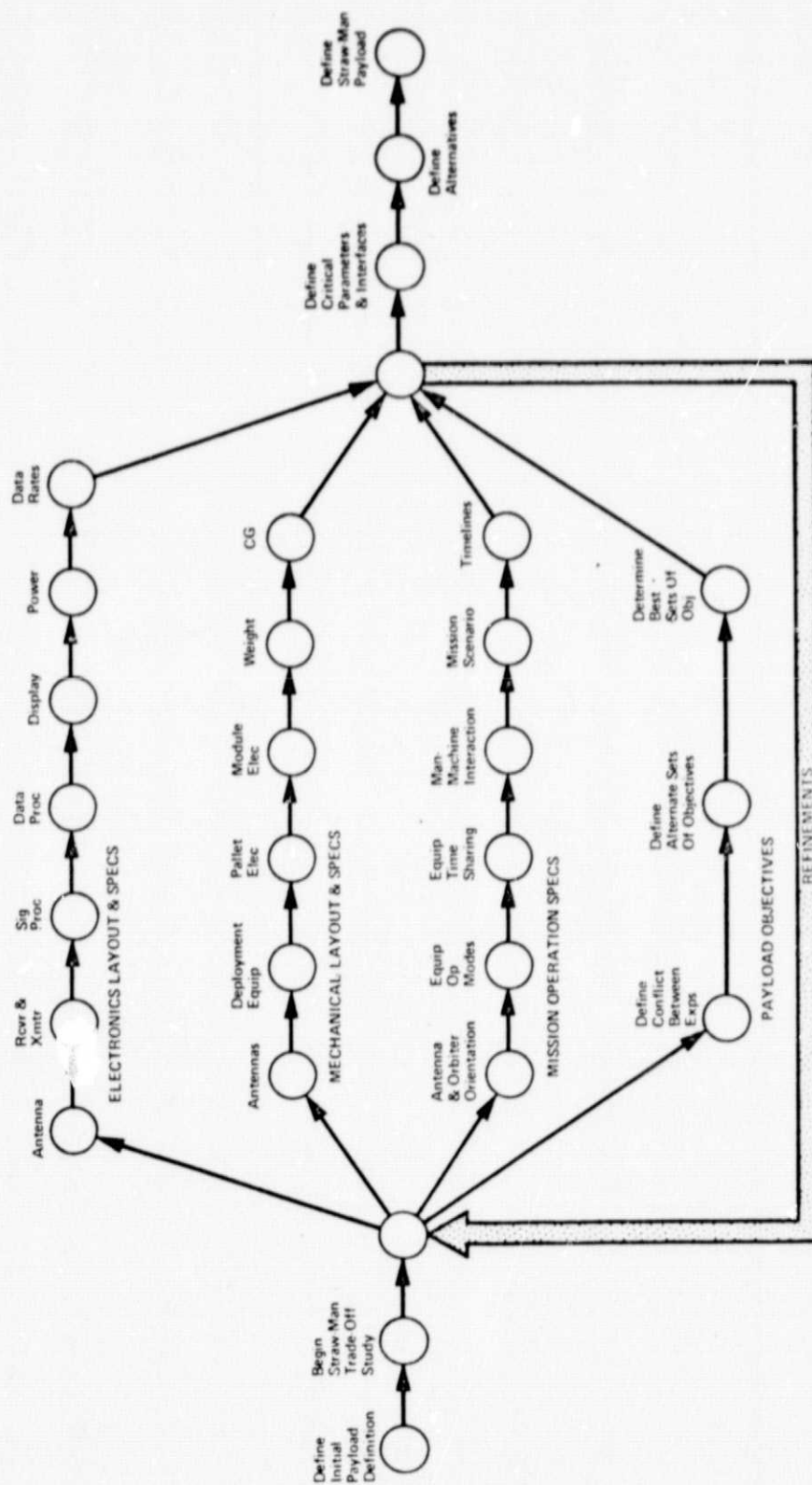


FIGURE 15



Month	JULY	AUGUST	SEPTEMBER
Year	1975		

6. SUMMARY

The study indicates that the physical size of the many large antennas required by these experiments can be accommodated by the Shuttle payload bay and that the Shuttle center-of-gravity requirements can be met. The results also show that the experimental objectives may be obtained by equipment which can be shared by several experiments, with only a small amount of hardware dedicated to specific experiments. The results indicate that the MMAP is feasible and can be an economical method of achieving a large number of experimental goals.

Other concepts of the MMAP are presently under consideration and should be studied in greater depth. Among these is a modular concept in which parts of the MMAP may be flown on a particular mission with other experiments. As an example, one module might consist of the Upper Antenna Cluster and its associated electronics. This module could meet the requirements of six of the twelve experiments and would occupy only one pallet. Other concepts are being investigated which do not utilize the pressurized module so that additional instruments may be installed in the forward section of the bay.

Study in greater depth of these and other variations of the original concept should be carried out in the near future. The tasks required are outlined in Section 5.